Gansman & Moore '04

Power Plant Test

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Thesis

presented for

the Degree of B.S. in M.E.

by

Lea Moore & Harry Meyer Gansman.

1904.

Commercial Efficiency Test

of the

Power Plant

of

The Moore and White Co. Phila'da.

1904.

Modern business methods demand that economy be practiced in all departments of a manufacturing establishment. Until recently, and then only in the larger places, no attempt has been made to discover and eliminate the many sources of loss. But with the keen competition and the advance of the science of engineering, the great saving that could be accomplished in the mechanical end of the plant has become apparent, and it is recognized at present more than ever before that the generation of power and transmission of the same is of vital importance.

To know exactly what the different apparatus is doing and that it is working to the best advantage, it is desirable that periodical tests be made. In the older plants this is quite laborious as no provision has been made for doing this thing. At the same time it is most desirable that a plant be tested under the ordinary working conditions, and the losses determined. From the present point of view it pays to remodel a plant and install modern machinery, even if one could get along with that already in use. To

determine if this saving will warrant the outlay, the efficiencies of the different machines should be ascertained.

This is what we tried to do in our work. As the plant has increased in size new machines have been installed, but no provision has been made for testing, the makers' claims having been accepted as conclusive. We have tried to determine the power losses in some directions and the efficiencies of different parts of the power plant under running conditions. These conditions are likely to be quite different from those in the makers' laboratories.

In order to do this it was necessary to arrange many devices, some of which were only temporary while others were permanent so that in the future the firm could use them for tests of a similar nature.

The steam for the plant is generated by a horizontal return tubular boiler rated at 150 H.P. It is equipped with damper regulator, water back, Cockrane feed-water heater and smoke consumer. The water back consists of a nest of tubes placed in the front part of the furnace and through which

the water circulates. The smoke consumer, more properly "smoke preventer", consists of a number of flues between the walls of the setting; they receive air from the ash pit and deliver it above the fire. Normally, the openings to these flues are covered; but upon opening the fire doors, they are uncovered by a system of levers and the heated air is permitted to flow through the flues. After the fire doors are closed the openings are gradually covered again, complete covering taking place in from one to two minutes, the time depending on the quality of the fuel. This gradual closing is effected by means of a dash-pot.

How well the device succeeds in preventing smoke is a matter of conjecture. It was installed by the Patentee under a guarantee to save ten per cent in fuel. One of the objects of the test was to determine the efficiency of this device.

Boiler Tests.

There were two boiler tests;the first with smoke consumer and water back in use and the second without them. The intention was to run the second test without the smoke consumer only,but the water back sprung a leak after the first test and was disconnected permanently. Since the combined use of the water back and smoke consumer did not show a saving of ten per cent,we decided that another test to determine the efficiency of the smoke consumer alone was unnecessary.

Pennsylvania bituminous coal was used in both tests.The boiler was fed with cold water from reservoir tank as shown in diagram on page . Circumstances necessitated the placing of the weighing tank (see photo on page 7) on the second floor. From this tank the water flowed to the reservoir below and was then pumped to the boiler.

In measuring Heating Surface we have used the areas of the fire side of tubes,the back tube sheet,and that part of the shell over which the gases had a free path.

The quality of the steam was measured by a throttling calorimeter placed just above the main stop valve on the top of the boiler. See tabulated results of tests on pages 13, 14, & 15. The method used in starting and stopping the tests, was that of Professor Spangler.

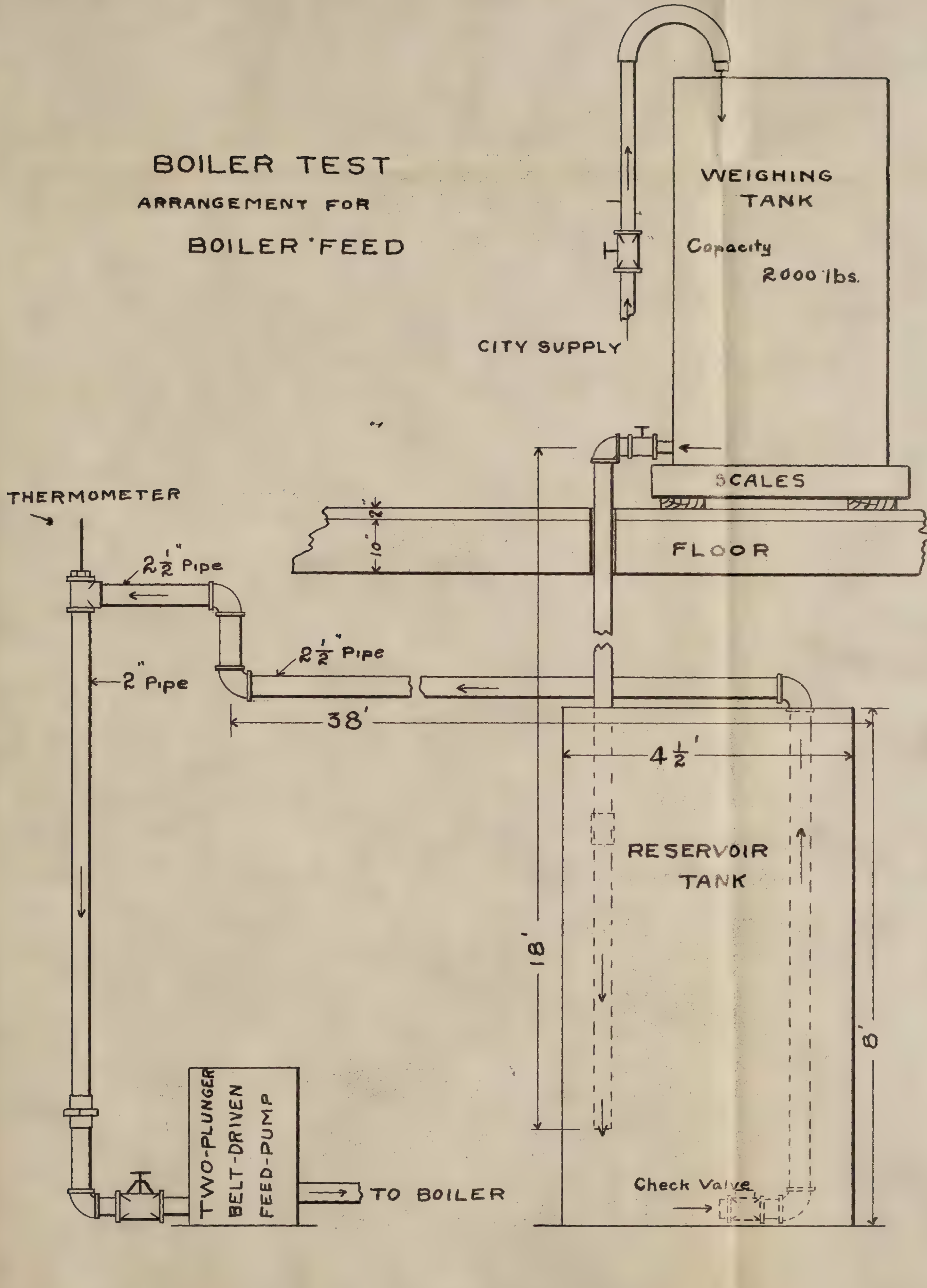
The Engine.

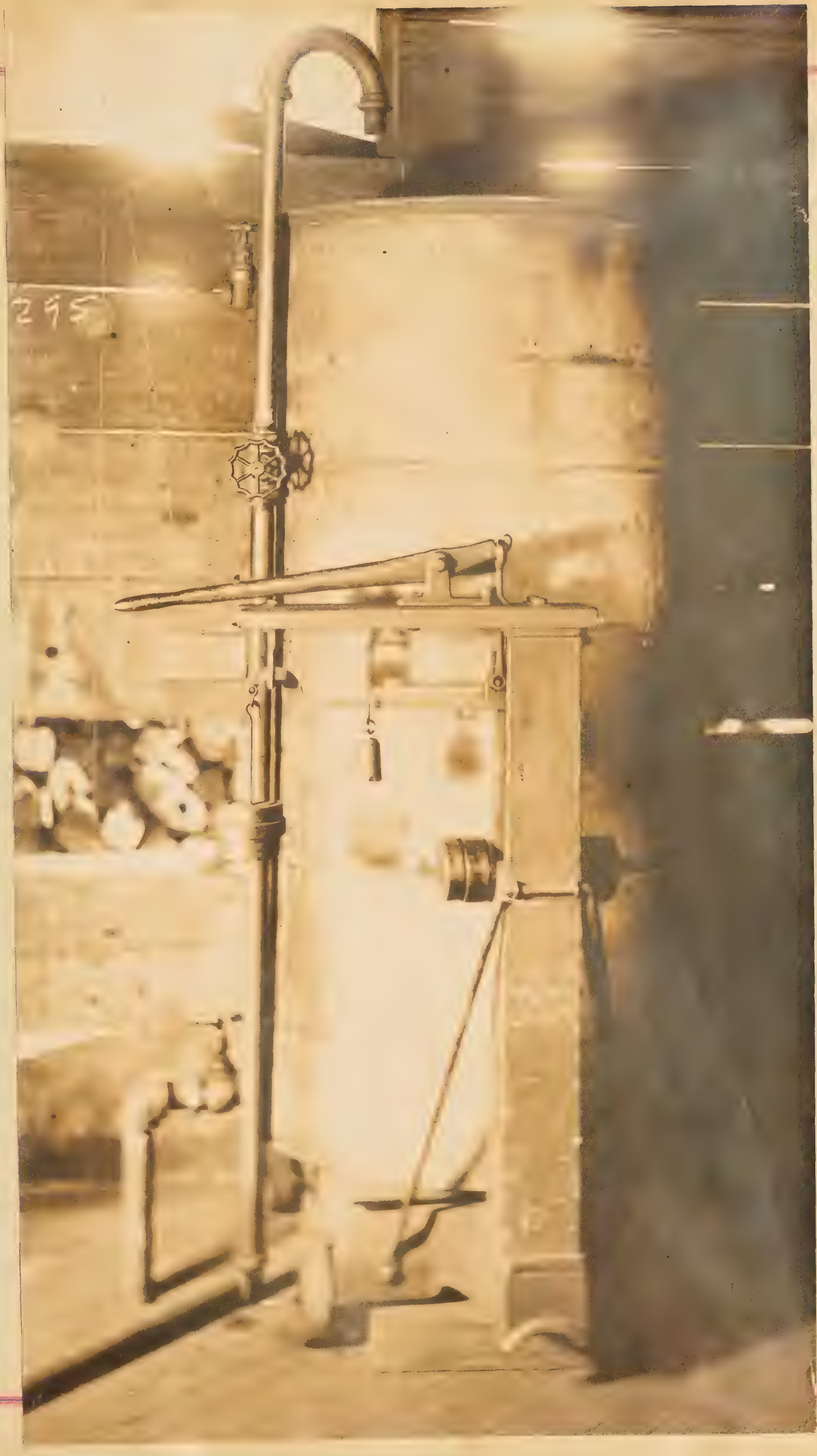
The engine in an Improved Greene, 16 21/32" X 36" making 87 R.P.M. rated at 125 H.P. and fitted with a Porter balanced governor. It drives the line shafting at 150 R.P.M. the engine flywheel being ten feet diameter and twenty-four inches face. See photo page 9.

Reducing Rig.

The reducing rig used on all engine tests was of the pendulum type. See photo page 8. The bottom of the pendulum rod was fitted with a turned pin which moved up and down in a vertically slotted guide (iron) bolted to the cross-head pin. The reduced motion was transmitted by indicator cord over two sets of pulleys to the indicators.

BOILER TEST
ARRANGEMENT FOR
BOILER FEED

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The first test on the engine was the one to determine the load variation during the day(to be referred to later)and on this day only,was one indicator used. The pipe connections ions were made from either end of the cylinder to the indicator located midway and cards were taken by opening the valves at one end and then at the other. Most of these cards showed the steam throttled at admission. The cause was found to be due to the long pipe connections and small valves used at the cylinder;consequently on all later tests two indicators were used with short pipe connections and cards taken simultaneously from either end. No trouble was experienced thereafter. The same "Star" outside spring indicators were used throughout the tests.

Load Test.

On Feb.15 '04 the variation in load during the day was determined by taking cards every fifteen minutes. This load was quite variable on account of the intermittent load

upon the generators and air compressor. These machines may or may not have been taxed heavily just as the cards were taken. This sudden variation in load may be seen from the differences in M.E.P!s of the head and crank ends since the cards from each end were taken within a quarter of a minute of each other. The date of the run shows that there was a large lighting load early in the morning and again in the evening. Data and results are tabulated on pages 16,17&18 and the curve on page 19.

Data and Results

of

Boiler Tests and Load test on Engine.

Boiler Tests conducted at the plant of the M & W Co.

No.1 - with Smoke Consumer and Water Back in use.

No.2 - without them.

Number of test	1	2
Date of test	May 16	May 23 '04.
Duration of test	11 h,35 m.	11 38
Sq.Ft.grate area	37.5	37.5
Sq.Ft.heating surface	1149	1149
Ratio of heating surface to grate area	30.62	30.62
Average steam pressure	81.4	83.8
Average barometer	28.82	29.89
Absolute steam pressure	96.05	98.48
Draft,in inches of water	.36	.38
Average temperature of fire room (F)	83	102
" " " outside air	62.8	78
" " " flue gases	700	658
" " " feed water	72.5	77.5
" " " steam	320.5	322.6

	1	2
Total fuel in lbs.	5693.5	5643
Per cent moisture	2.75	2.1
Dry fuel in lbs.	5541	5527
Total refuse	526.5	607
Total combustible	5014.5	4920
Total fuel per hour	491.5	485
Total combustible per hour	432.9	423
Quality of the steam in % vapor	99.76	99.84
Total water	43033	40071
Water corrected for x	42950	40011
Equivalent evaporation from and at 212	50348	46883
Equivalent evaporation per hour	432 8,	407 0.
Water evaporated per lb.dry fuel	7.766	7.239
Equivalent evaporation per lb.dry fuel	9.08	8.48
Equivalent evaporation per lb.combustible	10.03	9.53
Dry fuel per sq.ft.grate per hour	14.77	14.73
Equiv.evap.per sq.ft.heating surface per hour	3.76	3.507
Commercial H.P.	145.9	135.8

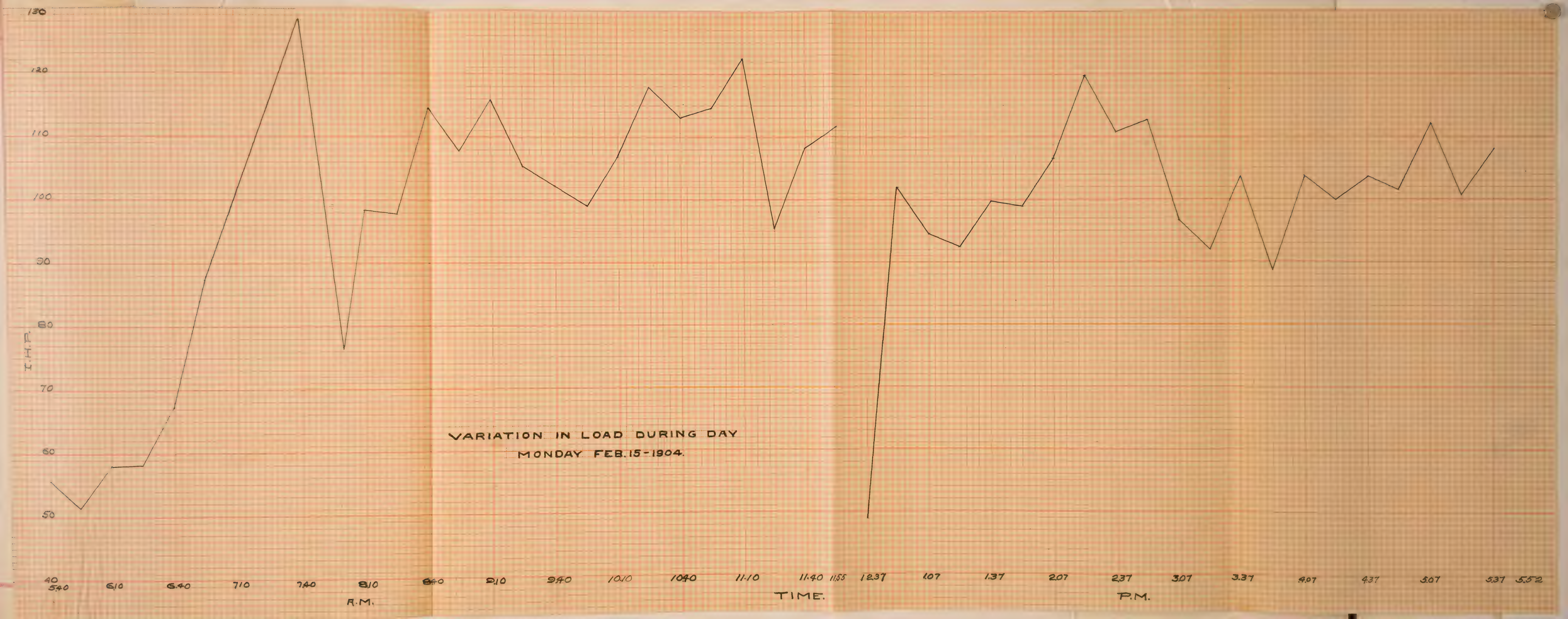
	1	2
Per cent Rating	97.2	90.0
Flue Gas Analysis (average of twelve samples)		
Per cent CO_2	8.12	8.05
" " O	11.16	11.34
" " CO	0.14	0.34

LOAD TEST. FEB. 15-04.

M.E.P.H	M.E.P.C	R.P.M	I.H.P.H.E	I.H.P.C.E	I.H.P.TOTAL	TIME
17.9	14.8	86.7	30.8	25.0	55.8	5.40
15.4	14.3	87.0	26.6	24.8	51.4	5.55
17.4	16.7	86.5	30.0	28.1	58.1	6.10
17.4	16.8	86.4	30.0	28.2	58.2	6.25
22.7	16.9	86.4	39.0	28.3	67.3	6.40
29.2	22.5	86.4	50.1	37.8	87.9	6.55
40.1	35.4	86.4	68.9	59.5	128.4	7.40
30.2	27.8	86.2	51.8	46.6	98.4	8.11
30.0	27.2	86.0	51.4	46.5	97.9	8.23
35.1	31.9	86.0	60.1	54.5	114.6	8.38
32.1	31.9	85.8	54.8	53.1	107.9	8.53
38.4	30.4	85.6	65.4	50.5	115.9	9.0.6
31.1	31.4	85.8	53.0	52.3	105.3	9.23
31.5	29.2	85.8	53.6	48.6	102.2	9.38
30.2	28.7	85.6	51.4	47.7	99.1	9.53
31.5	32.0	85.6	53.6	53.2	106.8	10.08
39.8	30.2	85.6	67.7	50.2	117.9	10.23
34.3	32.9	85.6	58.4	54.7	113.1	10.38
36.2	31.9	85.6	61.6	53.0	114.6	10.53

M.E.P.H.E	M.E.P.C.E	R.P.M	I.H.P.H.E.	I.H.P.C.E	I.H.P.TOTAL	TIME.
40.7	32.0	85.6	69.2	53.1	122.3	11.08
28.6	28.1	85.6	48.7	46.7	95.4	11.23
35.0	29.2	85.6	59.6	48.5	108.1	11.38
35.6	30.6	85.7	60.7	50.9	111.6	11.53
14.7	14.1	86.7	25.3	23.6	48.9	12.37
34.6	25.4	86.3	59.4	42.6	102.0	12.52
32.6	22.8	86.4	56.1	38.3	94.4	1.07
27.6	26.7	86.4	47.5	44.9	92.4	1.23
30.5	28.3	86.2	52.4	47.4	99.8	1.38
30.3	27.9	86.2	52.0	46.8	98.8	1.53
34.0	29.0	86.0	58.1	48.3	106.4	2.08
43.3	27.5	86.0	74.0	45.8	119.8	2.23
32.2	27.8	85.6	54.8	46.1	100.9	2.38
28.1	32.9	85.7	48.0	54.7	102.7	2.53
28.6	28.9	85.6	48.6	48.0	96.6	3.08
30.4	23.8	86.2	52.1	39.9	92.0	3.23
33.8	27.1	86.1	58.0	45.5	103.5	3.38
29.1	23.1	86.4	50.0	38.7	88.7	3.53
34.7	26.2	86.2	59.5	43.9	103.4	4.08

M.E.P. H.E	M.E.P. C.E	R.P.M	T.H.P. H.E	I.H.P. C.E.	I.H.P. TOTAL	TIME.
31.8	27.0	86.4	54.6	45.3	99.9	4.23
32.0	29.0	86.2	54.9	48.6	103.5	4.38
30.7	29.2	86.1	52.6	49.0	101.6	4.53
33.6	32.7	85.9	57.5	54.5	112.0	5.08
32.8	26.5	86.1	56.2	44.5	100.7	5.23
37.8	25.7	86.1	64.9	43.1	108.0	5.38
33.0	29.1	85.6	56.0	48.4	104.4	5.53



VARIATION IN LOAD DURING DAY
MONDAY FEB. 15 - 1904.
I.H.P.
130
120
110
100
90
80
70
60
50
40
5.40
6.10
6.40
7.10
7.40
8.10
8.40
9.10
9.40
10.10
10.40
11.10
11.40
11.55
12.37
1.07
1.37
2.07
2.37
3.07
3.37
4.07
4.37
5.07
5.37
5.52
A.M.
TIME.
P.M.

Steam Consumption.

The load on the engine to obtain steam consumption was about equal to the average daily load. A comparatively steady load of this size was obtained partially the three generators loaded with arc and incandescent lamps, water rheostat and idle running motors; partially by running all line shafting and all available machines idle, while the balance of 20 H.P. was obtained by running the air compressor pumping against sixty pounds pressure and the reservoir tank exhausting through a valve to the atmosphere.

The plant is non-condensing, so the weight of water used was obtained from the boiler end in the same manner as the feed water was weighed for the boiler tests. The quality of steam was measured by a throttling calorimeter placed directly above the throttle valve of the engine. All pipes other than the main steam pipe to the engine were closed, so that all water pumped into the boiler was used in the engine.

After the load had been running for an hour, the test was started and cards and R.P.M. were taken every fifteen minutes. Since the quantity of water had to be measured from the boiler end, it was necessary to run the test for a long period. The run lasted nine hours.

	P.M	A.M
M.E.P.-Head end-	33.17	31.76
M.E.P.-Crank-	35.1	27.4
I.H.P.-Head end-	59.56	54.22
I.H.P.-Crank end-	58.22	45.63
Total I.H.P.	117.78	99.80
Duration of run - 9 hours -	5 hrs. 55 min.	3 - 5
Total I.H.P.hours	1004.77	
Quality of steam - % vapor	99.16	
Total water	30772 lbs.	
Total steam (corrected for x)	30463.9 lbs.	
Pounds of steam per I.H.P. hour,	30.3	

Line Shafting Friction.

We have made tests on the different sections of 1000 ft. of line shafting with its numerous counter shafts. The first test was to determine the friction using oil while the second test was run after using grease as a lubricant for three weeks. The results obtained while using grease were rather unsatisfactory on account of the governor not regulating close enough and thus giving varying cards. However, from the results when the cards were satisfactory, it is thought advisable to say that the grease lubricates better than the oil, since the I.H.P. is less.

Friction of lines in H.P.	Oil	Grease
First floor(north end)plus engine,	15.7	12.78
" " (south end)		2.92
Second floor(north side)	7.67	
" " (south side)plus 3 d south	6.41	
Third floor north	3.21	
Foundry	1.92	
Total	34.69	29.61

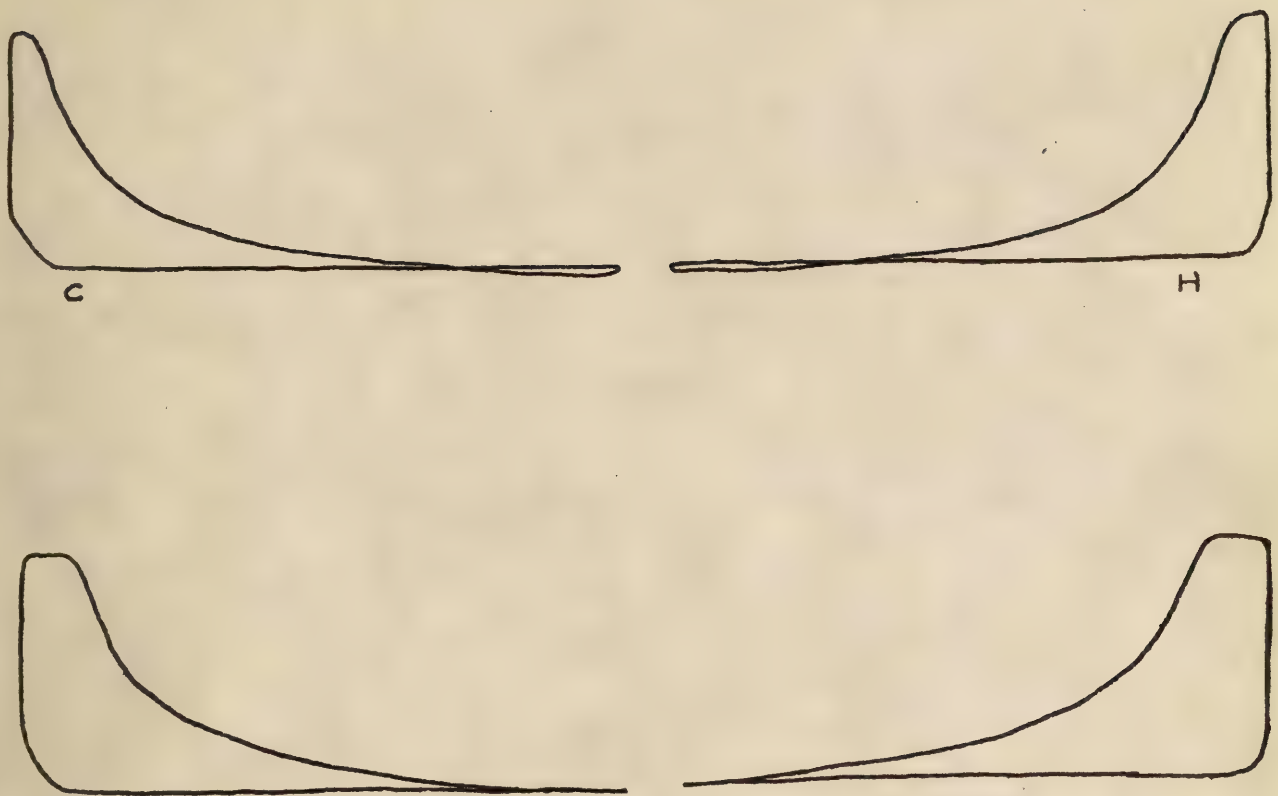
Brake Test.

The belt (24"wide) was cut and a brake as shown in photo on page 25 was placed on the flywheel. The side beams were of spruce(1 7/8" x 10" x 18 ft.)placed on edge. They were braced together by means of 7/8 x 34" bolts and struts of yellow pine held by 5/8 lag screws. The load was obtained by means of eight separate turns of 1 1/8" diameter rope each two turns being separately adjustable. There were two hand wheels holding two cross pieces which in turn held the hooks about which thimbles were placed to hold the rope and prevent cutting. The brake arm was 12 ft.1 1/8 in. a piece of triangular steel being placed in the end strut as a knife edge. This knife edge rested on a steel plate fastened on the top of an upright 6 x 6 support which in turn rested on platform scales,by means of which the load was weighed.

The zero was obtained by turning the flywheel in the forward direction and then backward;at first we found ~~that~~ that on turning the wheel backward,the brake lifted,so that a dead load was placed on the end and then the operation

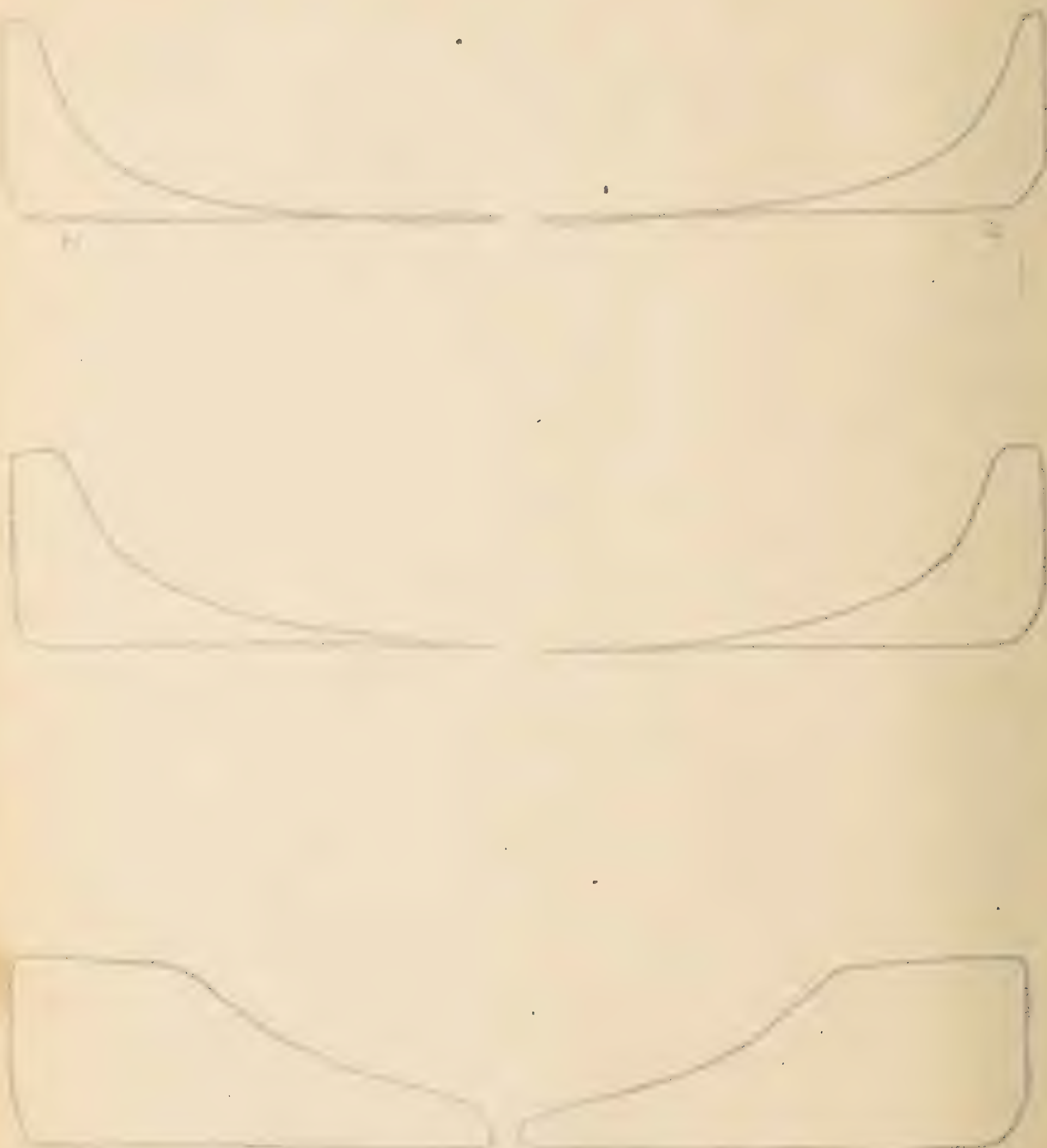
repeated. It was only necessary to subtract its weight from the zero obtained. The tests were run with from 40 to 160 H.P. on the brake. No cooling apparatus was used on the flywheel(25" x 121"). The heat remained concentrated in their rim(3" thick). Before taking data on each run, the engine with brake load was run from five to eight minutes to allow everything to become steady. The actual tests were short and the flywheel was allowed to cool byair currents through the engine room. R.P.M. were taken every minute, and three cards from each end of the cylinder on each run. Ten runs were made with the brake LOAD about ten H.P. apart.

The results tabulated on page are not satisfactory. We have an error which it has been impossible to find. The efficiencies vary from 100.3 % to 109 %, but if an efficiency of say 91 % is assumed and from the I.H.P. on the high load, a B.H.P. is obtained, and then this ratio of this new B.H.P. to the old B.H.P. be used as a constant to multiply all other B.H.P., then the efficiency determined with these new brake loads, values such as would be expected, are obtained.



TYPICAL INDICATOR CARDS.
125 H.P.

SPRING SCALE 60#



BRAKE TEST.

RUN NO.	M.E.P. H.E.	M.E.P. C.E.	R.P.M.	I.H.P. H.E.	I.H.P. C.E.	I.H.P. TOTAL
1	23.7	20.4	86.4	40.8	34.2	75.0
2	27.2	29.2	86.4	46.7	48.99	95.7
3	34.6	33.5	85.2	58.7	55.4	114.1
4	13.7	8.39	87.1	23.8	14.1	37.99
5	17.5	12.09	87.0	30.3	20.4	50.7
6	19.1	14.6	87.0	33.0	24.6	57.7
7	22.1	17.49	86.7	38.3	29.4	67.7
8	25.6	22.7	86.0	44.1	38.3	82.5
9	33.6	27.7	86.0	57.4	46.3	103.7
10	46.4	45.0	85.0	78.4	74.2	152.7

RUN NO.	SCALES GROSS	SCALES NET	R.P.M.	B.H.P.
1	500.5	394	86.4	78.3
2	621.5	515	86.4	102.3
3	716.0	609.5	85.2	119.4
4	309.	202.5	87.1	40.6
5	361.	254.5	87.0	50.9
6	405.5	299	87.0	59.8
7	457.5	351	86.7	70.2
8	559.5	453	86.0	90.3
9	653.	546.5	86.0	108.1
10	912	805.5	85.0	157.5

BRAKE ARM. 12' $1\frac{1}{8}$" BRAKE CONSTANT. .0023

ENGINE CONSTANT. H.E. .01988.

" " " C.E. .01942.

Generator Tests.

These machines are all belt driven from main line shafting through separate counter shafts. They all generate generate current and are designated as Nos. 1,2,&3.

No.1 is a 50 K.W. compound wound "Diehl" generator developing 400 amperes at 125 volts.

No.2 is a "Churchward type" compound wound dynamo with a capacity of 180 amperes at 125 volts.

No.3 is a 20 H.P. "Bullock" motor converted into a compound wound generator.

The loads required to test these machines were composed of arc and incandescent lamps,water rheostat and motors running light. The input was ascertained from the engine end by taking indicator cards of the following loads:-

Line shafting to first cut-off

Generator up to speed but field unexcited

Field excited but no current flowing in external circuit

External loads as shown in data.

Machines Nos.2 & 3 were not run with "field excited and

no current in external circuit" because the increase above the previous run seemed inappreciable. On this account the electrical efficiencies of these two machines were not obtainable.

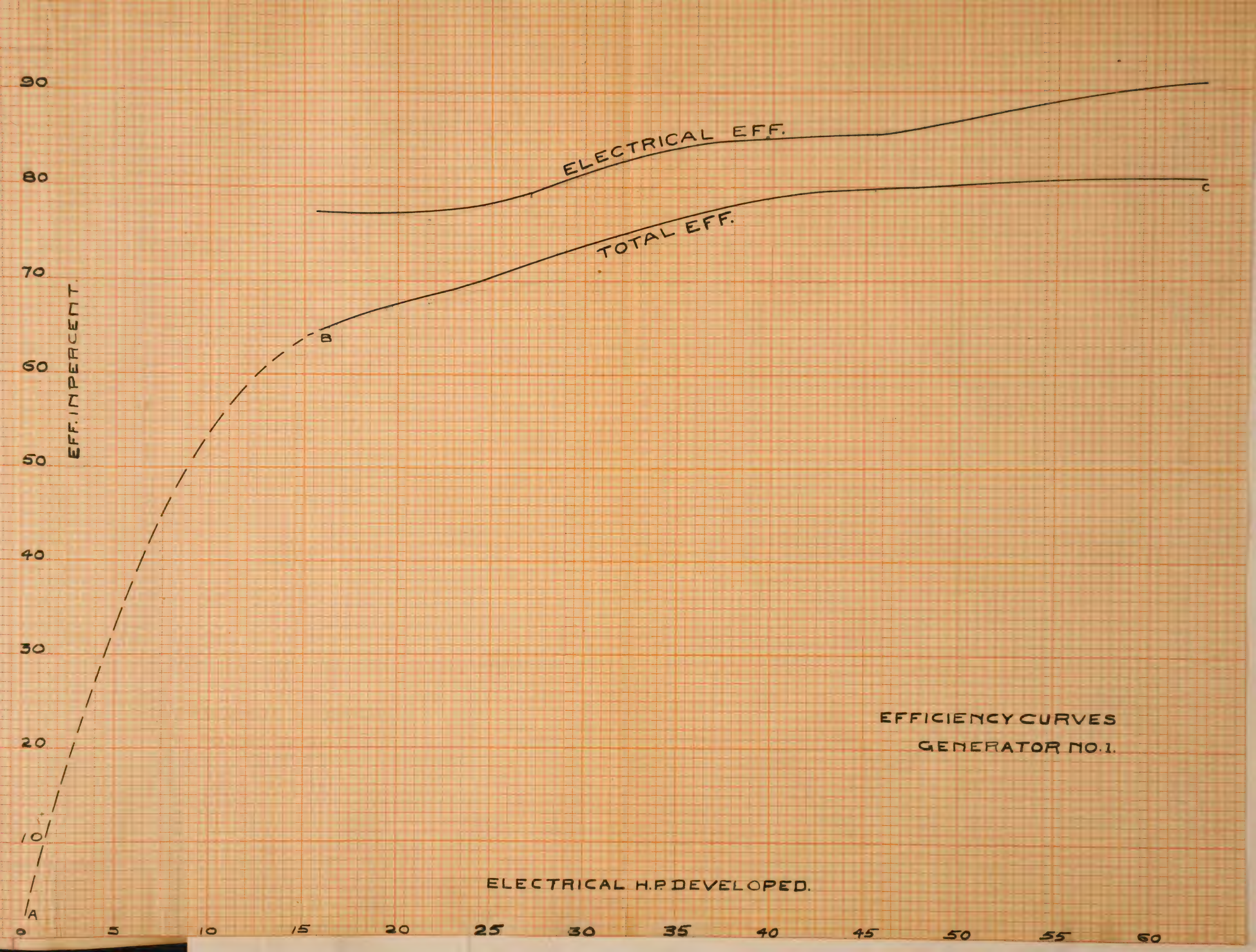
The total efficiency or the ratio of the electrical power developed to the power given off by the line shafting, was found for each of the three machines. This charges the losses in the drives to the dynamo, which is proper under the circumstances. In the case of No.1 machine, the "electrical efficiency" was obtained. This efficiency was taken as the ratio of the electrical power given off to the power put in, exclusive of mechanical losses. The curves are drawn with per cent efficiencies as ordinates and electrical H.P. as abscissae. Where the curve is dotted we had no points and assumed the direction.

Data and curves for No.1 follow on pages 29 & 30, those for No.2 on pages 31 & 32 and those for No.3 on pages 33 & 34.

GENERATOR NO. 1

M.E.P. H.E	M.E.P. C.E	R.P.M.	I.H.P. H.E	I.H.P. C.E	I.H.P. TOTAL
6.32	4.27	87.3	10.98	7.22	18.2
4.99	7.88	87.4	8.68	13.4	22.0
8.36	7.69	87.5	14.7	13.1	27.6
13.06	11.86	87.0	22.6	20.0	42.6
14.52	14.97	87.0	25.1	25.3	50.4
17.71	17.3	86.8	30.6	29.2	59.7
21.14	19.3	86.4	36.4	32.4	68.7
23.05	21.5	86.0	39.4	35.8	75.3
32.0	24.8	85.7	54.6	41.3	95.9

VOLTS	AMPERES	E.H.P.	COM. EFF.	ELEC. EFF.
0	0	0	0	0
0	0	0	0	0
114¼	0	0	0	0
114¾	103	15.8	64.8	77.2
112.8	143.5	21.7	67.6	76.4
113.¼	205.3	31.1	74.8	82.5
113¼	260.2	39.7	78.6	85.1
113¼	299.7	45.5	79.7	85.3
113¼	412.7	62.7	80.7	84.9

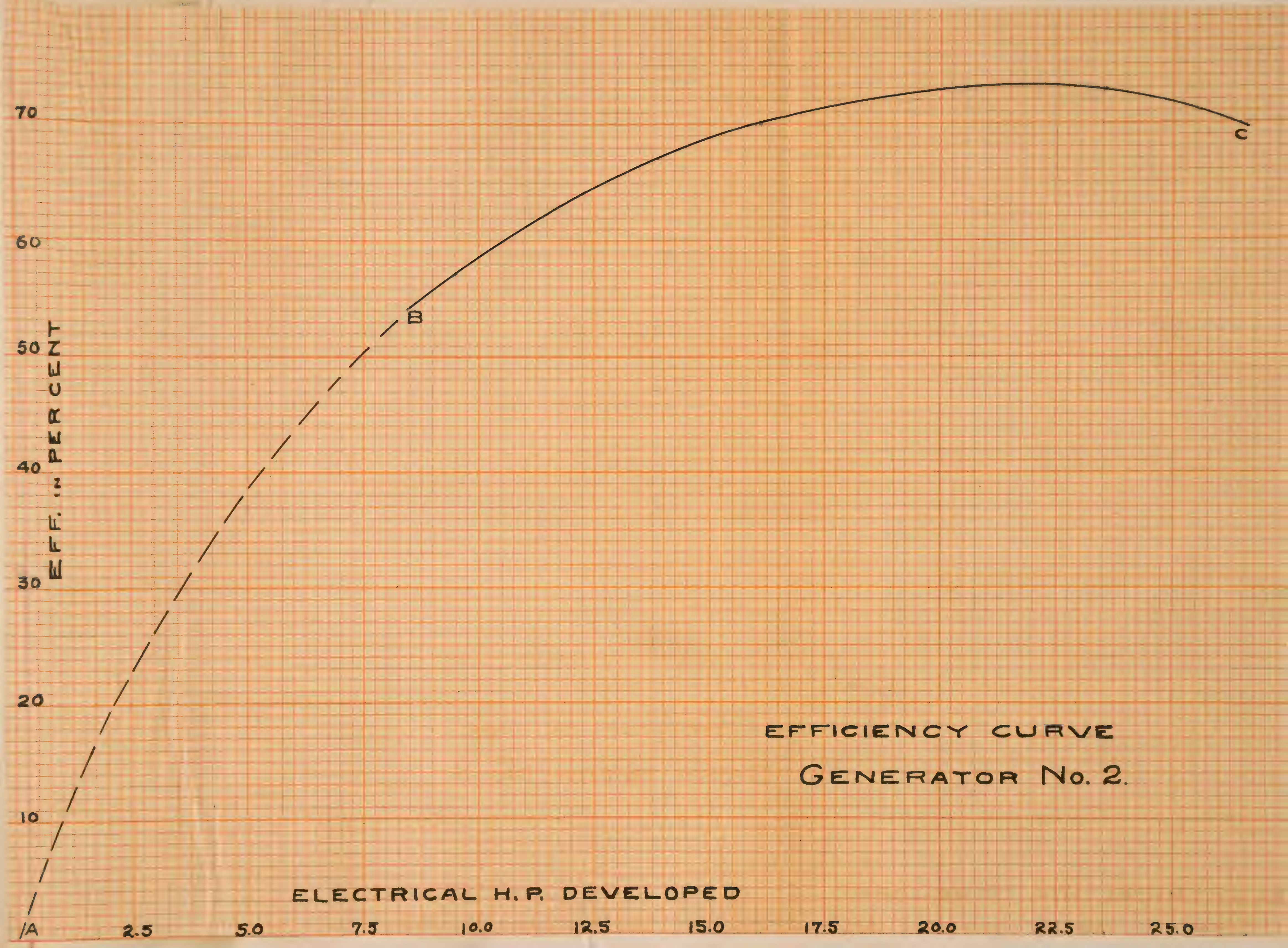


90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
30
35
40
45
50
55
60
EFF. IN PERCENT.
ELECTRICAL EFF.
TOTAL EFF.
A
B
C
ELECTRICAL H.P. DEVELOPED.
EFFICIENCY CURVES
GENERATOR NO. 1.

GENERATOR NO. 2.

M.E.P. H.E.	M.E.P. C.E.	R.P.M.	I.H.P. H.E.	I.H.P. C.E.	I.H.P. TOTAL
5.27	8.86	87.1	9.13	15.0	24.1
10.0	9.9	87.1	17.0	16.7	33.7
12.5	11.6	87.0	21.6	19.5	41.1
14.8	14.7	86.8	25.6	24.9	50.5
16.5	16.7	86.5	28.4	27.9	56.3

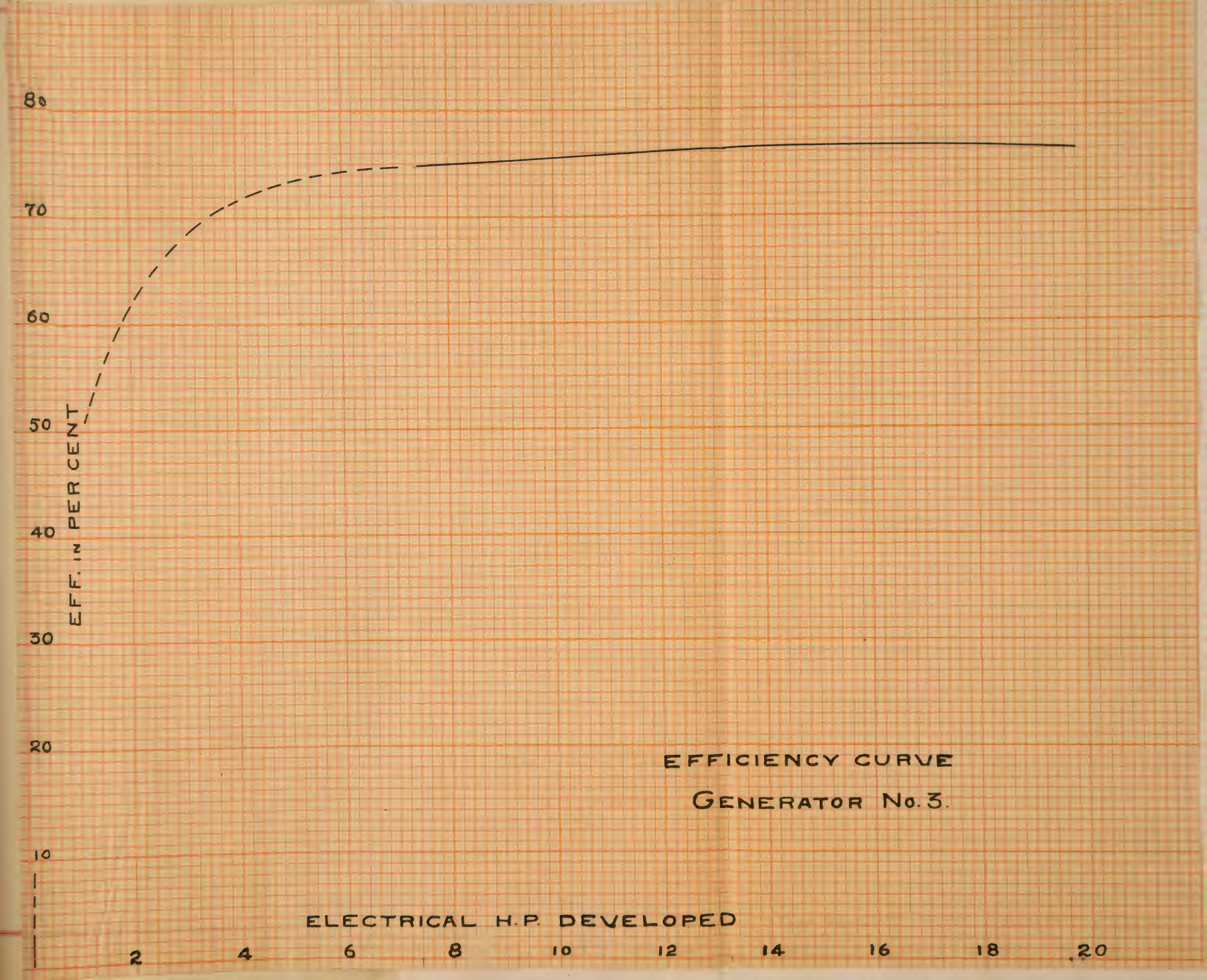
VOLTS	AMPERES.	WATTS	E.H.P.	EFF.
112 3/4	0	0	0	0
114 1/4	55.1	6030	8.45	54.6
114 3/4	104.6	12010	16.07	70.0
113 1/4	155.0	17590	23.52	72.8
109 3/4	180.5	19840	26.54	69.6


EFFICIENCY CURVE
GENERATOR No. 2.
EFF. IN PER CENT
ELECTRICAL H. P. DEVELOPED
70
60
50
40
30
20
10
/A
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
B
C

GENERATOR NO. 3.

M.E.P. H.E.	M.E.P. C.E.	R.P.M	I.H.P. H.E.	I.H.P. C.E.	I.H.P. TOTAL
4.99	9.33	87.2	8.66	15.8	24.4
5.88	10.68	87.1	10.05	18.0	28.1
9.52	11.32	87.0	16.48	19.1	35.6
13.47	12.68	86.1	23.1	21.2	44.3

VOLTS	AMPERES	E.H.P.	EFF.
112 3/4	0	0	0
113 3/4	48.6	7.4	74.8
112.6	87.7	13.24	76.2
110.5	133.7	19.79	75.9


EFFICIENCY CURVE
GENERATOR No. 3.
EFF. IN PER CENT
ELECTRICAL H.P. DEVELOPED
80
70
60
50
40
30
20
10
2
4
6
8
10
12
14
16
18
20

Calibration of Instruments.

Indicator Springs.

These were calibrated on the special apparatus for such in the Laboratory of the University of Pennsylvania, before and again after, running the tests. The results are tabulated on page 38, 41, and the curves on pages 40 & 42. The curves are plotted with rise of pencil as ordinates and pressure as abscissae. The mean of the ascending and descending curves being used.

Calibration of Voltmeters.

The Keystone Portable Voltmeter was calibrated by means of the Leeds Potentiometer and standard Clark-Carhart cell, just recently calibrated. (Calibration and curve-p 48, 49)

The Weston Switchboard Voltmeter was calibrated by comparison with the Keystone instrument. For calibration record and curve of calibration see pages 50 & 51 respectively.

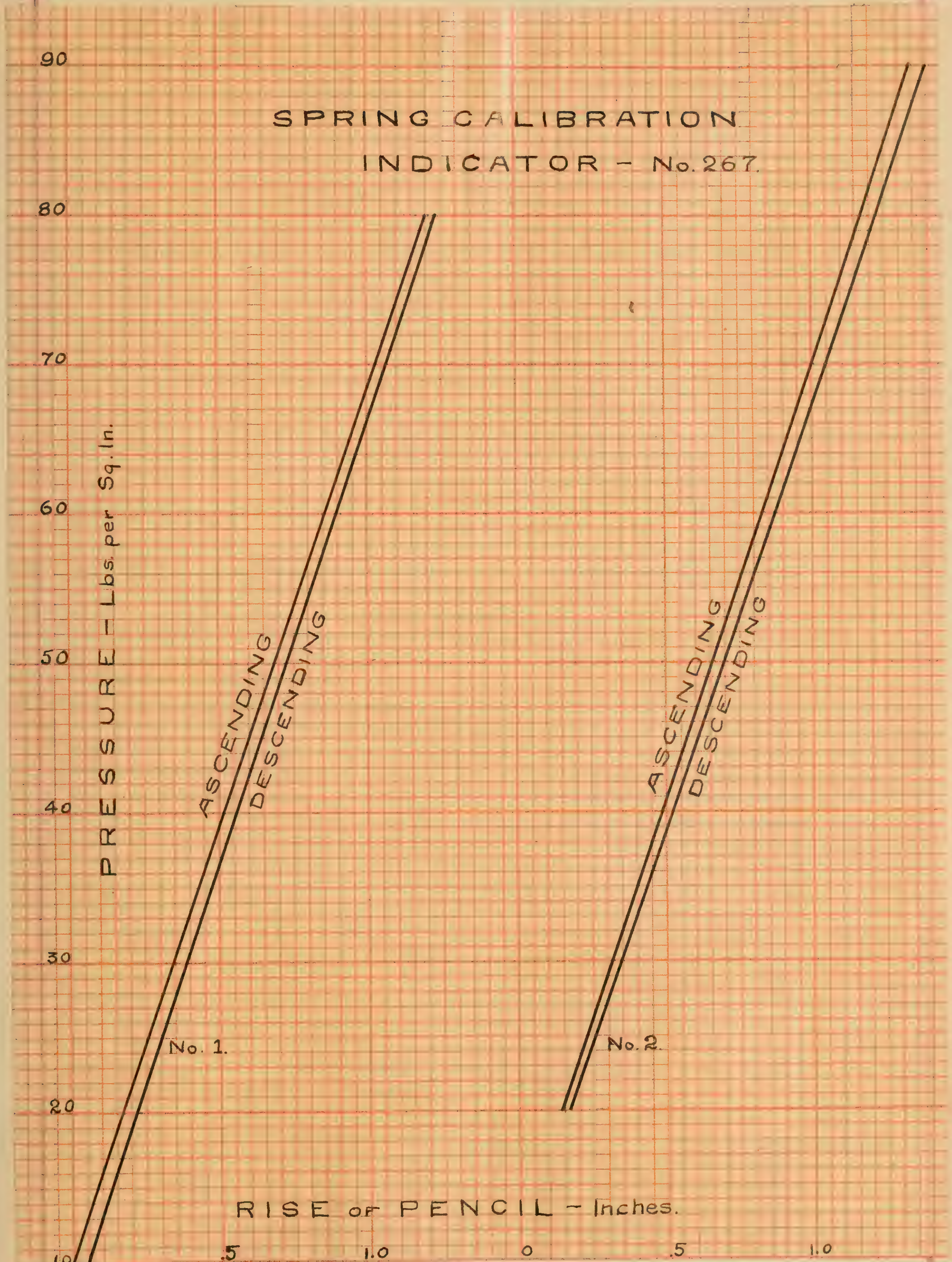
Calibration of Ammeters.

The Keystone Portable Ammeter was calibrated by

INDICATOR SPRING CALIBRATION.

#267.

LBS.	UP	DOWN	UP	DOWN
10	0	.3	0	0
20	.175	.23	.15	.17
30	.35	.39	.32	.35
40	.52	.57	.485	.53
50	.69	.73	.665	.705
60	.85	.91	.84	.87
70	1.03	1.07	1.01	1.05
80	1.21	1.23	1.23	1.22
90			1.35	1.40

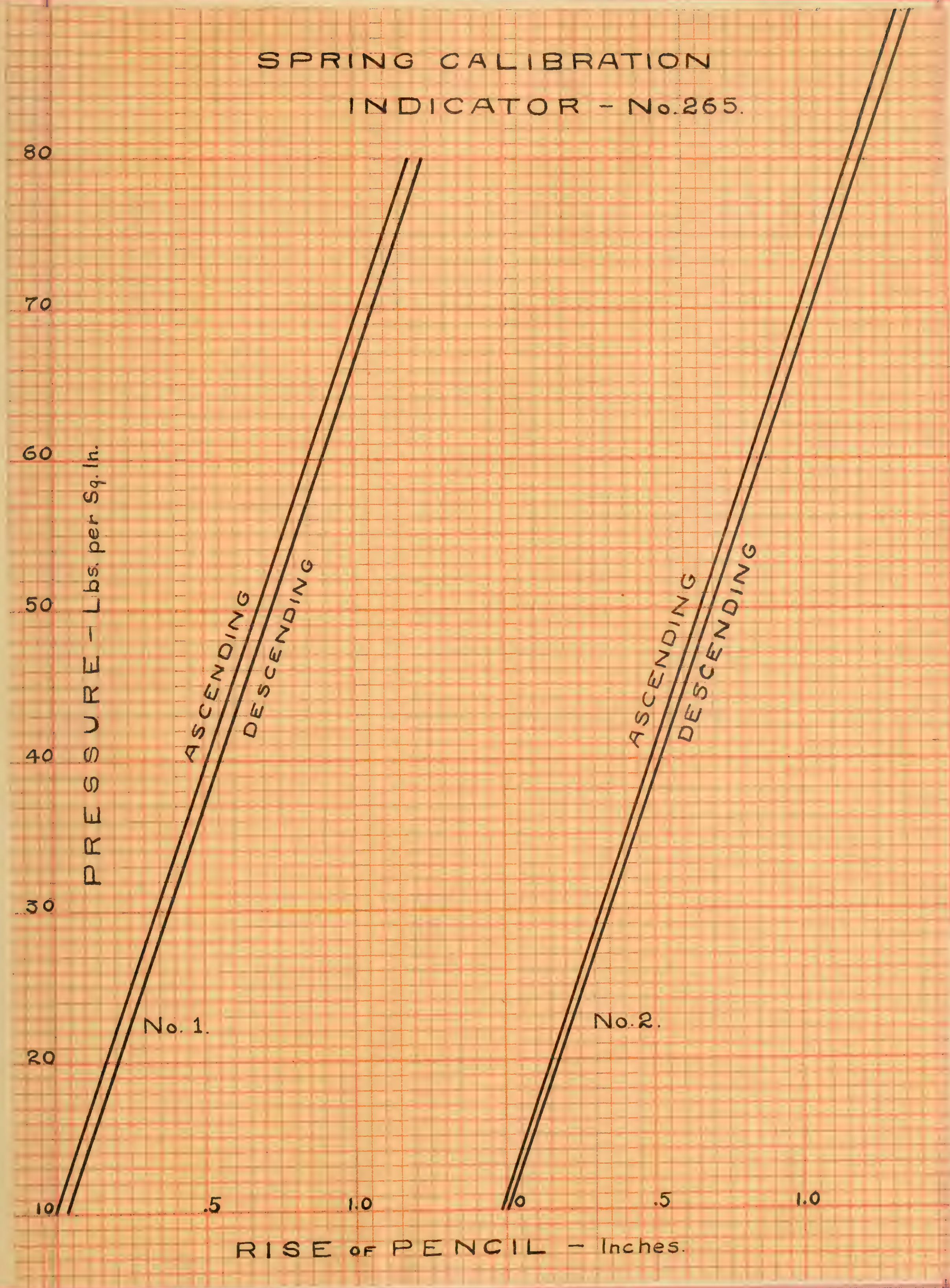

SPRING CALIBRATION
INDICATOR – No. 267.
90
80
70
60
50
40
30
20
10
PRESSURE – Lbs. per Sq. In.
ASCENDING
DESCENDING
ASCENDING
DESCENDING
No. 1.
No. 2.
RISE OF PENCIL – Inches.
.5
1.0
0
.5
1.0

INDICATOR SPRING

CALIBRATION.

#265

LBS.	UP.	DOWN	UP	DOWN
10	0	.015	0	0
20	.175	.21	.155	.175
30	.355	.38	.325	.355
40	.515	.565	.49	.53
50	.68	.72	.67	.70
60	.84	.90	.85	.88
70	1.015	1.06	1.00	1.03
80	1.19	1.23	1.17	1.22
90			1.35	1.39


SPRING CALIBRATION
INDICATOR - No. 265.
PRESSURE - Lbs. per Sq. In.
80
70
60
50
40
30
20
10
ASCENDING
DESCENDING
ASCENDING
DESCENDING
No. 1.
No. 2.
.5
1.0
0
.5
1.0
RISE OF PENCIL - Inches.

Calibration of

Keystone Portable D.C. Ammeter.

Range 0 - 200

True Amperes	Scale Reading
0	1.3
20	23.5
40	45.9
60	64.0
80	84.2
100	105.5
120	125.7
140	146.0
160	167.2
180	188.7
200	200 plus.

Calibration of

Weston D.C. Switchboard Ammeter.

Range 0 - 500

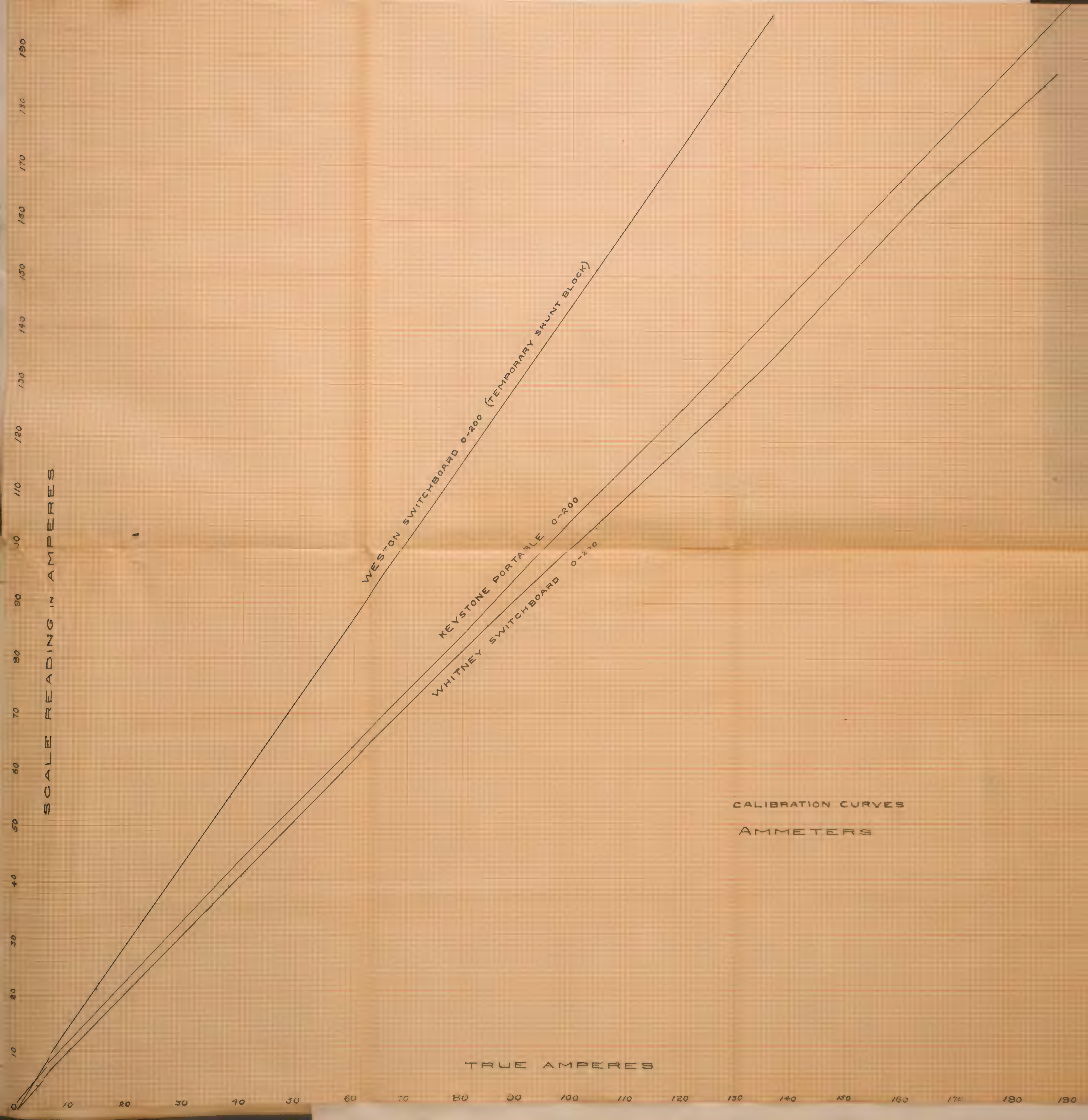
True Amperes	Ammeter Readings
0	0
50	50
100	100
150	148
200	198
250	246
300	299
350	349
400	400
450	451
500	502

Calibration of

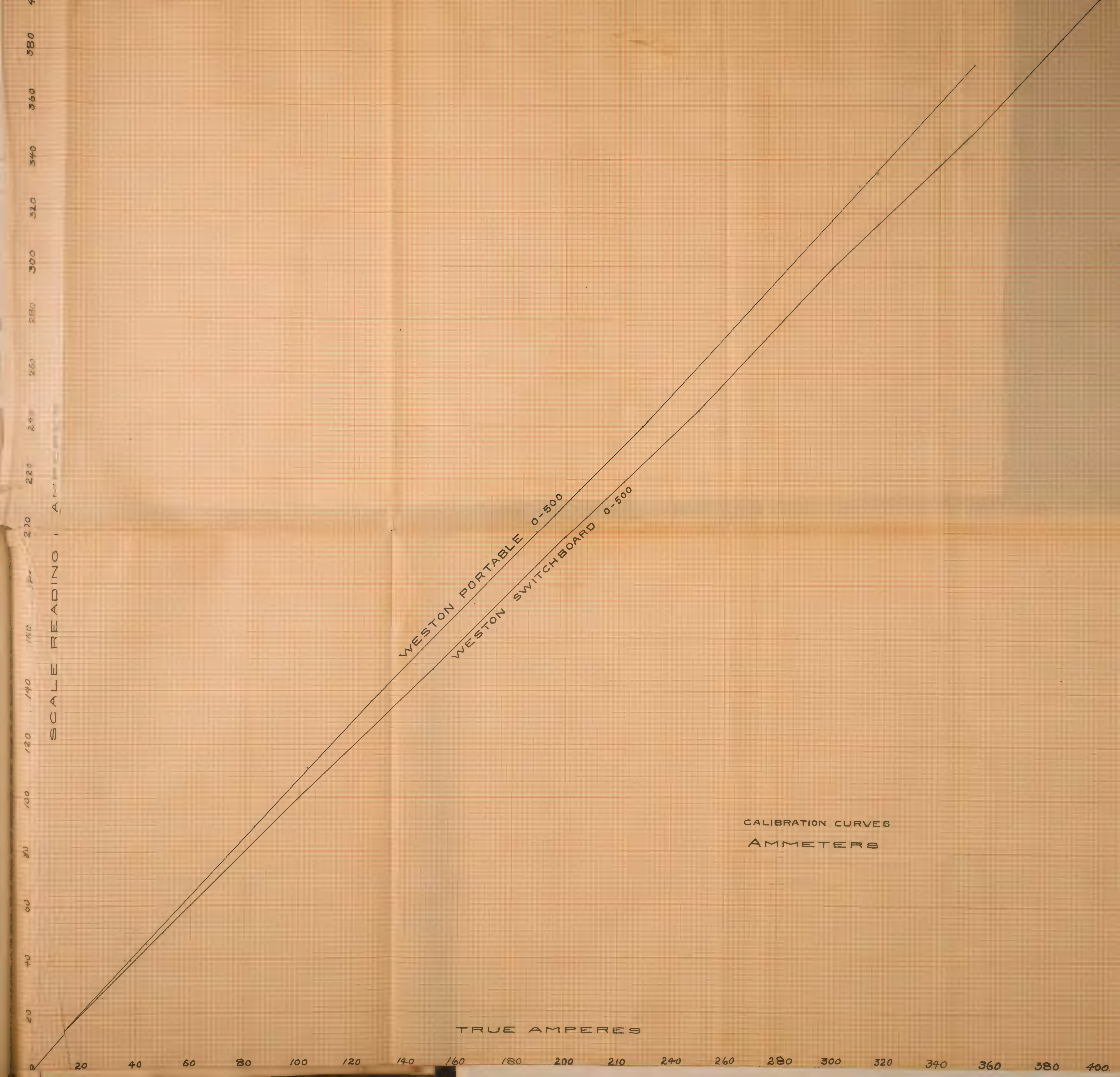
Weston Switchboard and Whitney Switchboard Ammeters.

Range 0 - 200 Range 0 - 200

True Amperes	Weston Reading	Whitney Reading
14.6	21	8
41	55	39
61.5	90	63
84.0	122.5	86
104.5	151	104
128	185	127
136.8	197	134
159.6		160
180		185
188		187



SCALE READING IN AMPERES
TRUE AMPERES
WESTON SWITCHBOARD 0-200 (TEMPORARY SHUNT BLOCK)
KEYSTONE PORTABLE 0-200
WHITNEY SWITCHBOARD
CALIBRATION CURVES
AMMETERS



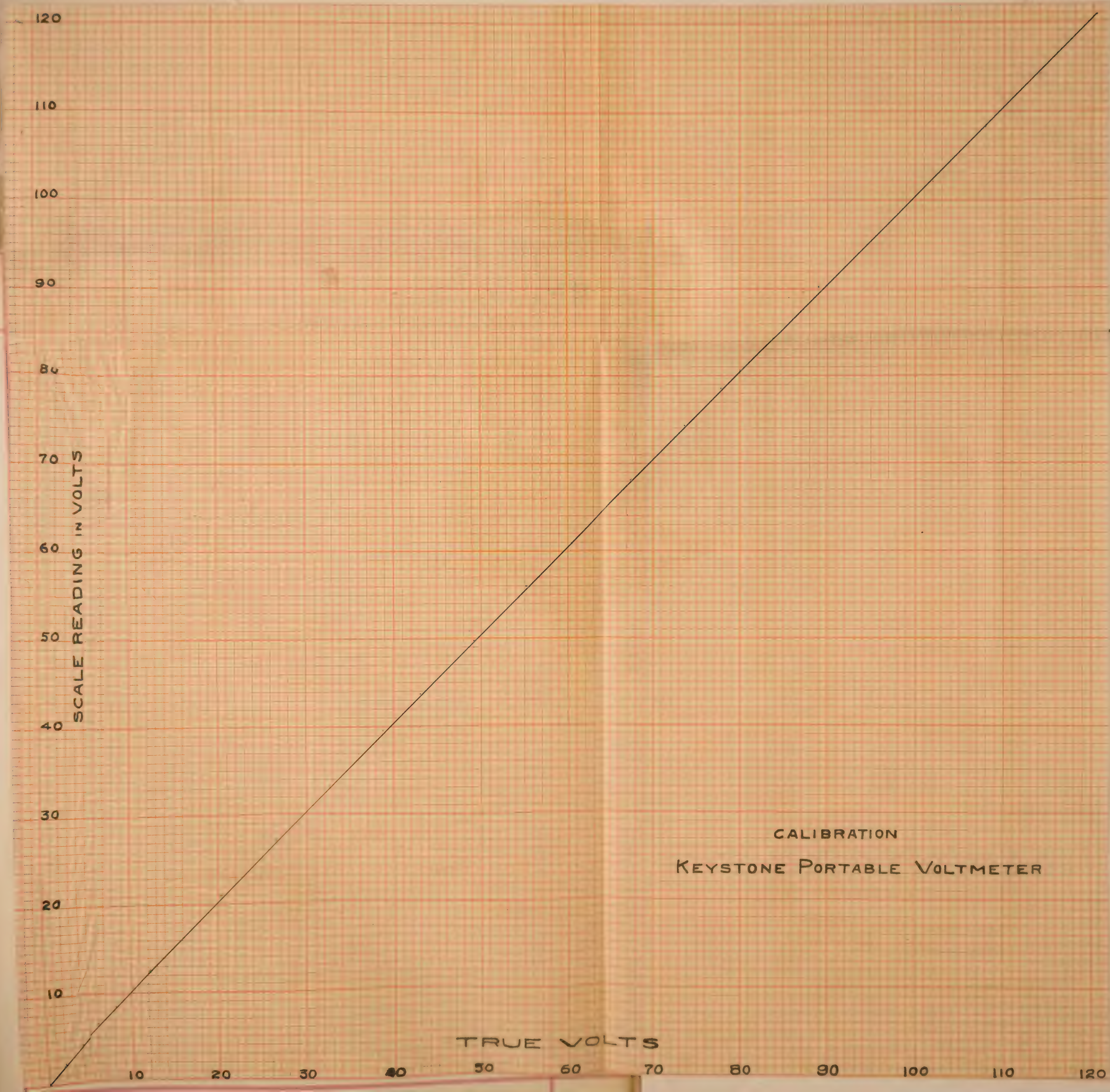
CALIBRATION CURVES
AMMETERS
WESTON PORTABLE 0-500
WESTON SWITCHBOARD 0-500
SCALE READING
TRUE AMPERES
20
40
60
80
100
120
140
160
180
200
240
260
280
300
320
340
360
380
400

Calibration of

Keystone Portable Voltmeter.

Range 0 - 150

True Volts(Potentiometer)	Reading
0	.1
2.5	2.25
4.05	4.3
6.13	6.5
8.16	8.5
10.21	10.7
12.24	12.7
20.45	21
26.64	27.1
32.85	33.2
38.94	39.6
42.98	43.8
49.13	49.9
55.26	56
61.39	61.9
67.51	68.1
73.64	74.2
77.9	78.5
83.91	84.3
89.98	90.2
95.92	96.2
102	102.2
108.04	108.3
114.11	114.2
120.54	120.8

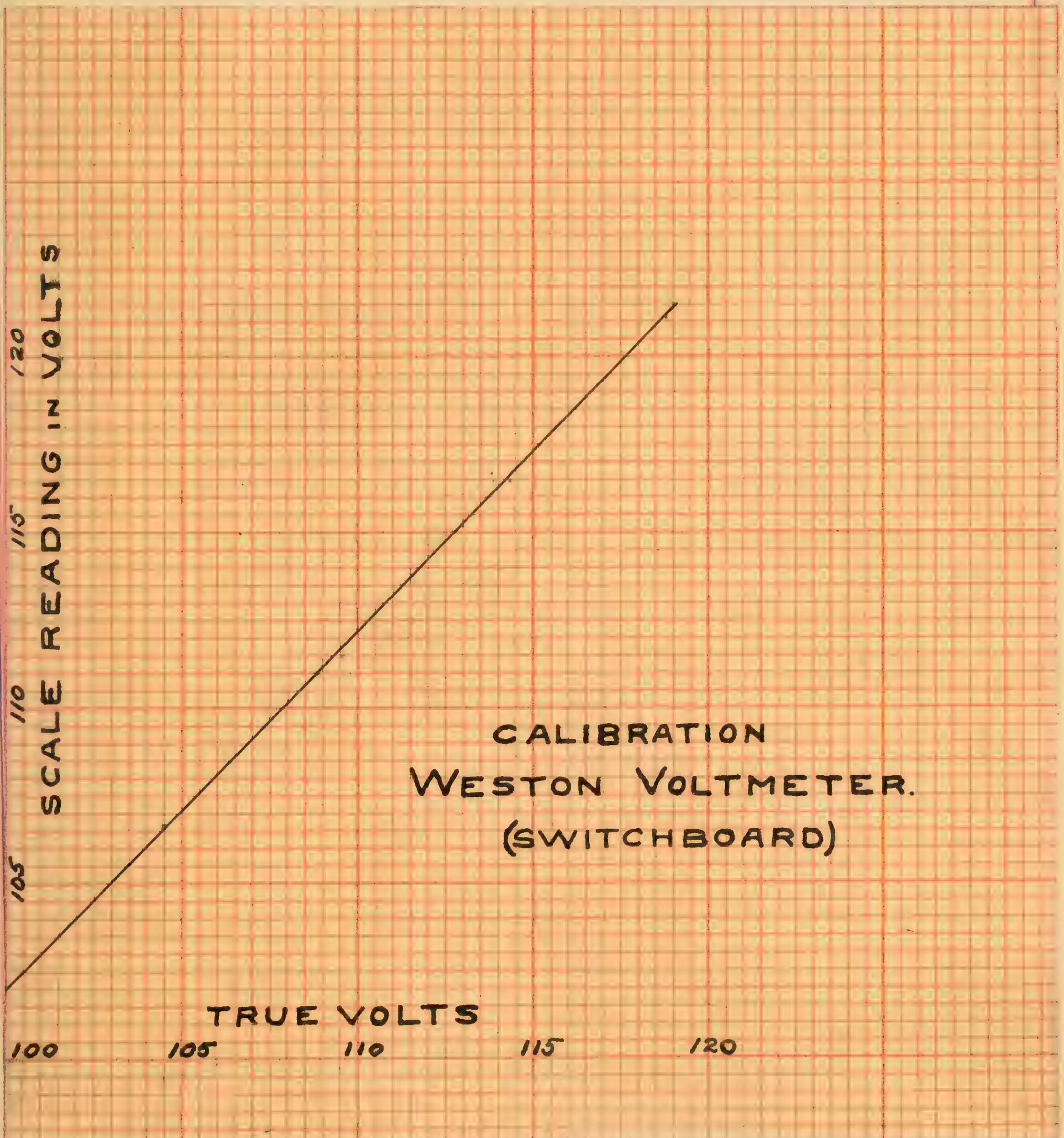

CALIBRATION
KEYSTONE PORTABLE VOLTMETER
SCALE READING IN VOLTS
TRUE VOLTS
10
20
30
40
50
60
70
80
90
100
110
120

Calibration of

Weston Switchboard Voltmeter.

Range 0 - 150

True Volts	Reading
104.5	106.6
108.8	111
109.2	111.8
113.8	116.6
114.3	116.4
119	121.5
118.7	121.1
98.5	100.5
98	100
98.9	101


SCALE READING IN VOLTS
105
110
115
120
CALIBRATION
WESTON VOLTMETER.
(SWITCHBOARD)
TRUE VOLTS
100
105
110
115
120

Calibration of

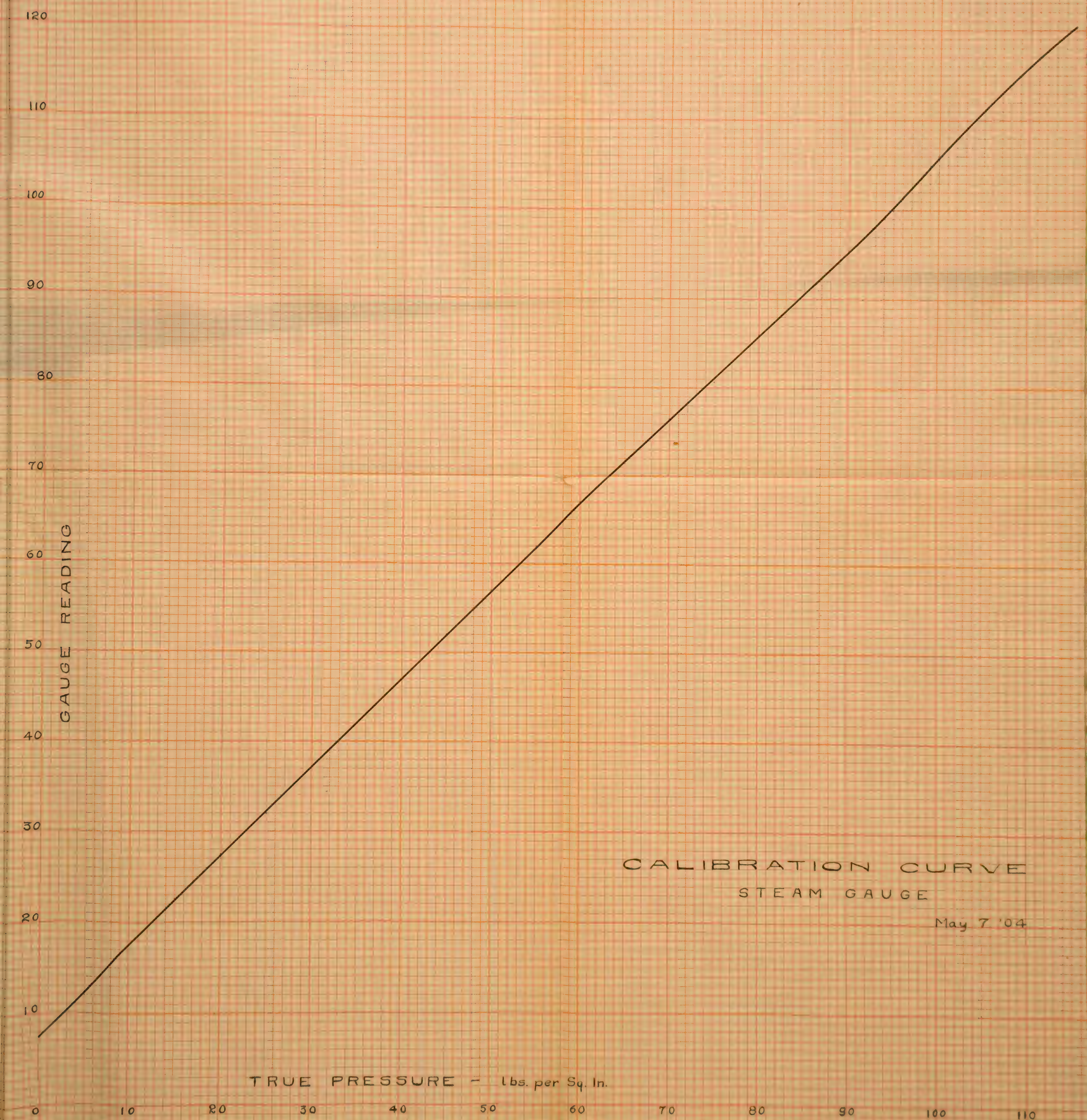
Weston 0 - 500 Portable Ammeter.

True Amperes	Scale Reading
15	15
38	40
44	46
61.5	65
83.9	89.5
10[illegible]	111
127	136
135.5	145
144	150
159.9	170
1[illegible]3	191
187	197.5
205	216
219	240
263	277
310.2	330
317	335
353	375

Calibration of

Steam Gauge

True Pressure(lbs.per sq.in.)	Gauge Reading
0	7.5
5	12
10	17.5
15	22.5
20	27.25
25	32
30	37
35	42
40	47
45	52
50	57
55	62
60	67
65	71.5
70	76.5
75	80.6
80	86
85	90.5
90	95.5
95	100
100	106
105	111
110	116
115	120.25


CALIBRATION CURVE
STEAM GAUGE
May 7 '04
GAUGE READING
TRUE PRESSURE - lbs. per Sq. In.
0
10
20
30
40
50
60
70
80
90
100
110
120

Calibration of

Platform Scales.

Poise	Stamped Weight (lbs.)	Stamped Equivalent in lbs. on beam	Actual Equiv.
1	1	100	99
2	2	200	200
3	3	300	300.5
4	4	400	400
5	3	300	290.5
6	3	300	294.5

Conclusions.

In figuring the saving due to the combined use of the water back and smoke consumer,we have thought it best to base our values on per lb. combustible,since the tests were a week apart and the coal came from different mines although of practically the same grade. The combined saving is 5.7 %,and as the water back was guaranteed to save 10 % and the smoke consumer was also guaranteed to save 10 %,they have failed signally from this point of view. When feeding cold water we think the water back is a decided advantage in adding to the steaming,but the smoke consumer does not fulfill its purpose. The boiler is giving satisfactory results,as can be seen from the data of the tests;but we would advise the raising of the steam pressure to 100 lbs.

The engine is working very economically for one of its kind: an I.H.P. hour on 30.3 lbs.of steam,and we think raising the steam pressure would better this performance. Incidentally to the steam consumption test we have that

the air compressor uses 20 H.P.

The generators work as efficiently as could be expected with the poorly arranged drives. The total efficiency would be considerably improved in the cases of Nos.1 & 2 if the drives to those machines were corrected. Generator No.1 runs excessively hot, which we are confident is due to enormous C^2R losses and which seems to us to be characteristic of Diehl machines.

Generator No.3 is working to better advantage than we were led to believe it would do. It is a shunt motor converted into a compound wound dynamo and the total efficiency shows up well with the other machines.

We find that the power absorbed in the line shafting is much less than has been estimated, by engineers employed to report upon the subject. We are led to believe from our results that the power required to drive it using grease as a lubricant is much less than when using oil.

From the difference in the quality of the steam at the top of the boiler and at the throttle valve of the

engine, we conclude that the cork covering on the steam pipe is very efficient; the quality on boiler being 99.76 and at the engine 99.16 with a length of pipe of 35 ft. containing three ells.